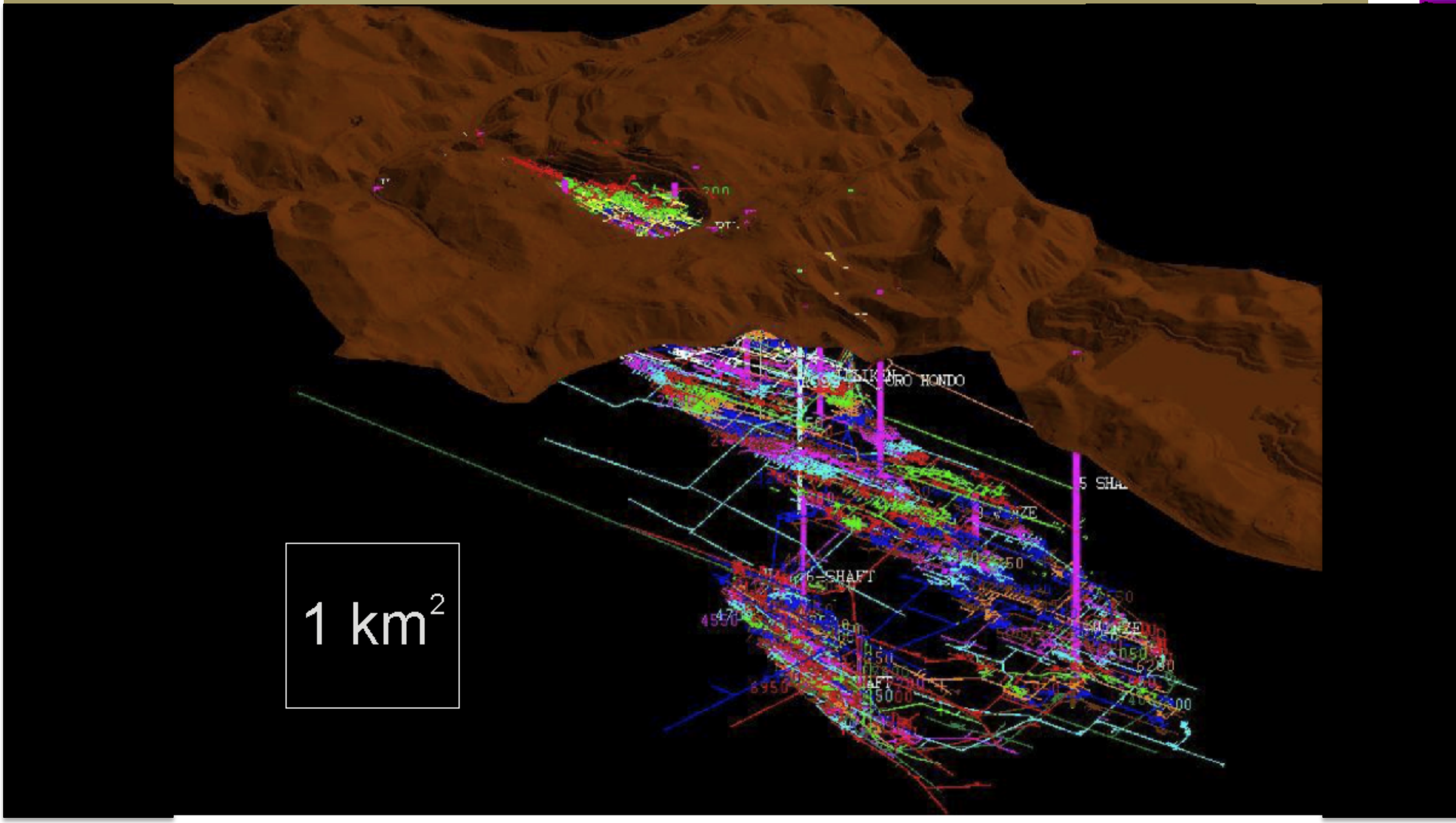
Biology-Geoscience-Engineering at Homestake DUSEL



DUSEL BioGeoEng Proposed Experiments

Distributed Experiments

CMMI	Baseline Characterization	Stettler (SDSMT); Anderson (BHSU) + 4 others
CMMI	Fiber-Optic Monitoring of R. Masses	Wang (UWM) + 6 others
S4	Deep EcoHydrology	Boutt (UMass); Kieft (NMT); Wang (UWM) + 8 others
S4	Subsurface Imaging and Sensing	Glaser (UCB) + 19 others
	Mobile Underground Laboratory – MUL's	Pfiffner (UT) + others

Facility-Based Experiments

S4	CO_2 Sequestration	Peters (Princeton); Oldenberg (LBNL) + 6 others
CMMI	Coupled THMCB Processes	Sonnenthal (LBNL) + 6 others
	Low Dosage Radiation Biology	McTaggart (SDSMT) + 11 others
S4	Faulting Processes	Germanovich (Georgia Tech) + 7 others

Large Cavity Experiments

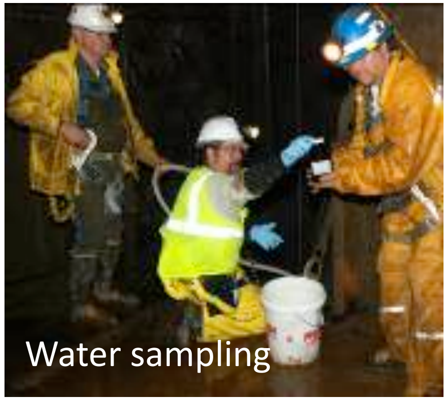
S4	Cavern Design for DUSEL	Einstein (MIT); Bobet (Purdue) + 8 others
	Mechanics of Engineered Fractures	Labuz (UMN) + 12 others
	Large-Scale Unconfined Compressive Test	Fairhurst (UMN)

Baseline Characterization

Objective: Make time-critical measurements to characterize subsurface conditions. Science objectives and support ISEs needs.

Approach

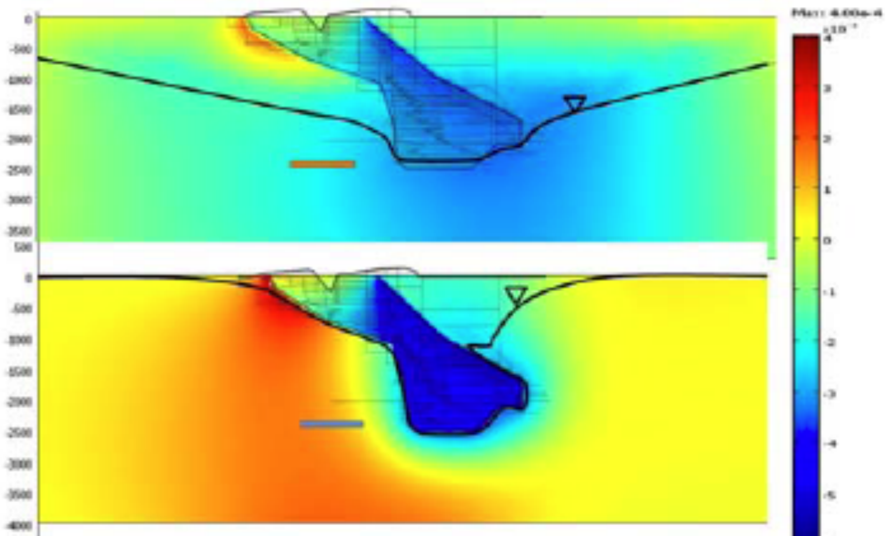
1. Dewatering
   - Archive water samples—chemistry and microbiology
   - Hydraulic head
   - Deformation
2. Subsurface
   - Map fractures
   - Collect biofilm samples
3. Database
   - Update the Vulcan database
   - Develop management protocol


Water sampling


Long baseline tiltmeter

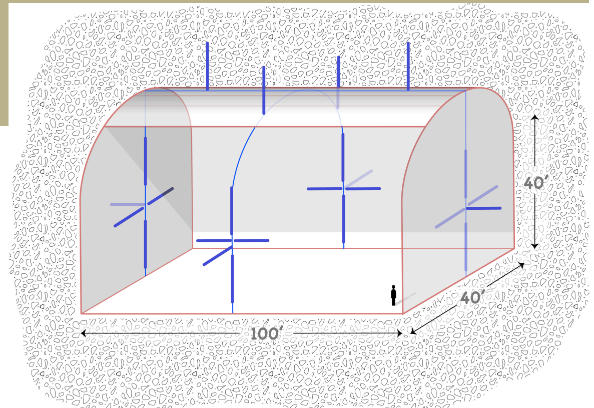
Fiber-Optic Strain Monitoring of Rock Masses in Large Underground Facilities

Herb Wang, U. Wisconsin-Madison
Dante Fratta, U. Wisconsin-Madison
Mary MacLaughlin, Montana Tech
Larry Murdoch, Clemson
Alan Turner, Micron Optics
Steve Gabriel, Spearfish High School



Vol. Strain during dewatering, Regional Scale

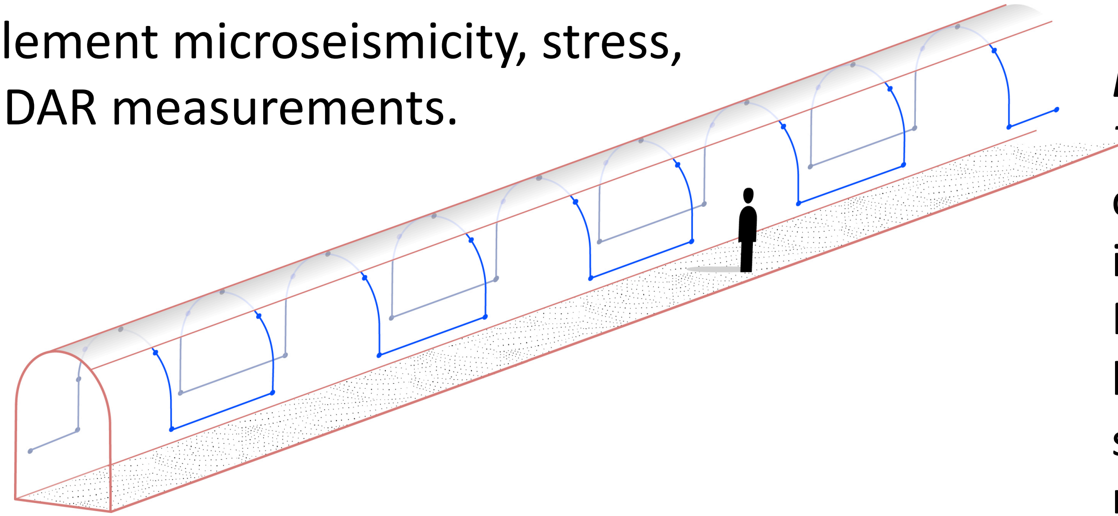
Fiber-Optic Strain Monitoring of Rock Masses in Large Underground Facilities



Science Goals

- Understand rock deformation over multiple scales of length (cm to km) and time (secs to decades).
- Advance technology for characterizing rock deformation.
- Perform long-term (decadal) structural health monitoring (SHM) of DUSEL.
- Complement microseismicity, stress, and LIDAR measurements.

Fiber-Bragg Grating (FBG) sensors are discrete. Scale of measurement is 1 cm to 2 meters with 1-$\mu\varepsilon$ sensitivity.

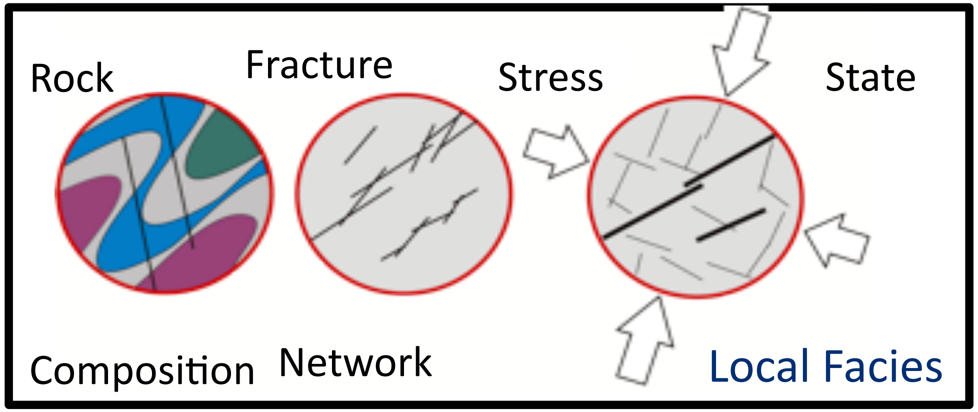


Distributed Strain and Temperature (DST) is continuous. The optical fiber itself is the sensor. Scale: Measurement can extend to kilometers with 30-$\mu\varepsilon$ sensitivity and 1-meter spatial resolution.

Deep EcoHydrology Experiment

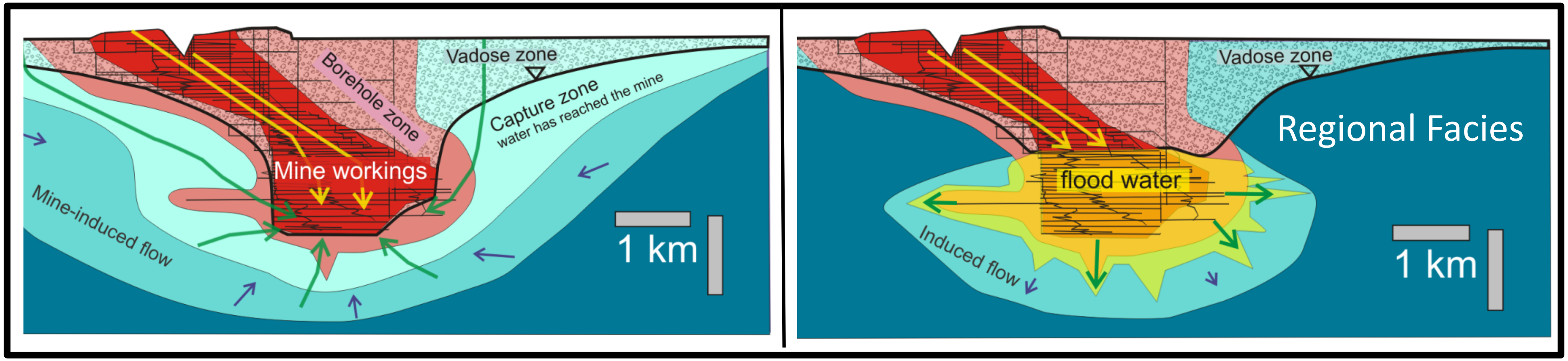
Univ. of Mass. Bout, NMIT - Kieft, Clemson - Murdoch and many others

The distribution and evolution of subsurface life are controlled by processes related to geology, geomechanics, and hydrology.

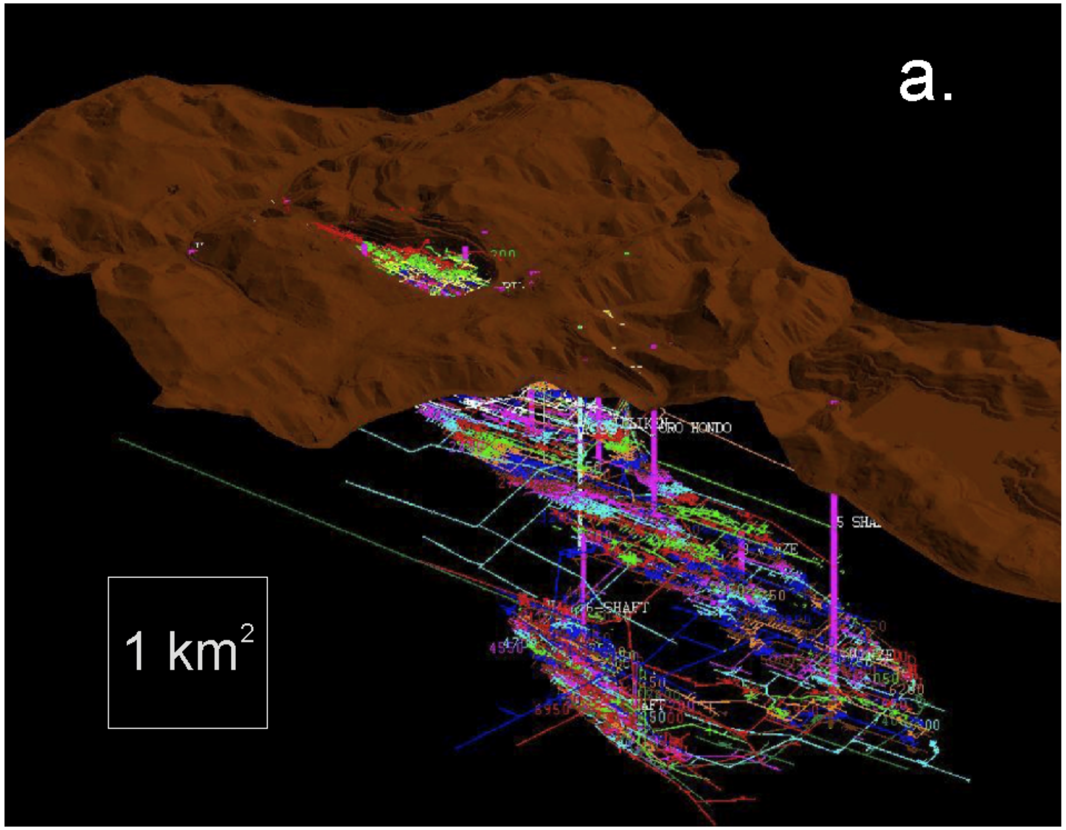


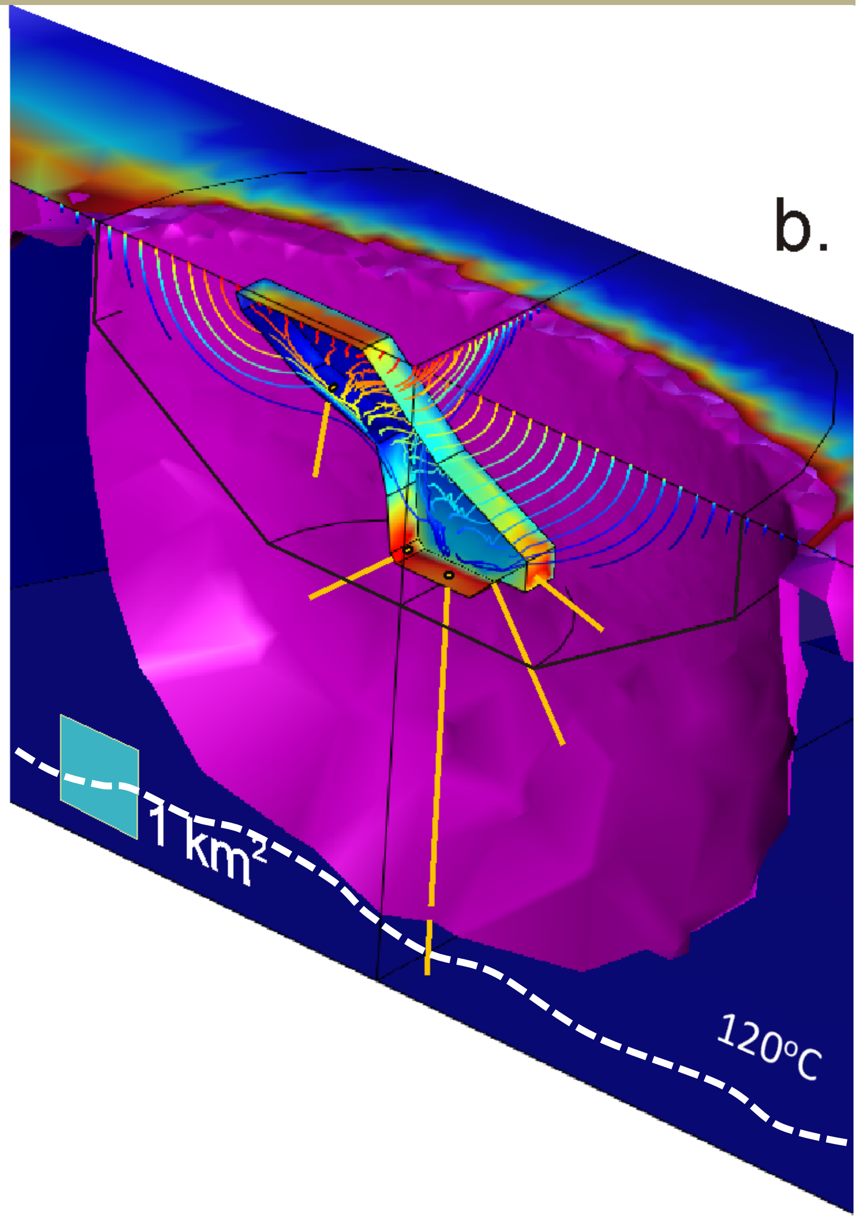
Approach

- Sentinel Boreholes - Flooding/ dewatering event and construction of lab perturbs system. Monitor response to characterize bio, hydro, chemistry, mechanics, other
- Drill, monitor and manipulate local to understand facies with MUL's.
- Drill deep for limits of life; additional pre-proposal to ICDP



Deep EcoHydrology Experiment





Subsurface Imaging and Sensing

Objective: Develop, refine, deploy geophysical techniques for imaging.

Homestake Transparent Earth Observatory	Steven Glaser, UC Berkeley, Bill Roggenthen, SDSMT, Lane Johnson, LBNL	**Project Safety**	Subsurface Imaging and Sensing Team
Active source experiment to study anisotropy	Gary Pavlis, Indiana University	**3D resistivity & self-potential monitoring of the mine dewatering phase**	Burke Minsley; US Geological Survey, Denver
Installation of the Rapid City long-period station at the Homestake	Lind S. Gee, scientist-in-charge USGS Albuquerque	**Underground Gravity Wave Observatory**	Riccardo DeSalvo, CalTech; Vik Mandic, UMN
Seismic Sources – micro to macro	Lane Johnson, LBNL, Bill Roggenthen, SDSMT, Steven Glaser, UCB	**Advanced Imaging of Gravity Variations and Rock Structures**	Don Pool, USGS, Phoenix; Joe Wang, LBNL
Prototype Broadband Array for DUSEL	Gary Pavlis, Indiana University	**From Earthquakes, to Lightning, to Mine Safety**	Friedeman Freund , NASA,-Ames and Team
3D, Time-Lapse Seismic Tomography for Imaging Overburden Changes due to Dewatering	Erik Westman, Virginia Tech	**Rock Imaging Using X-Ray Tomography**	Giovanni Graselli, University of toronto
Stress Monitoring with high precision seismic travel time measurements	Fenglin Niu, Rice U; Paul Silver Carnegie Institute, Tom Daley, LBNL	**Quantum Dots and Microspheres to Determine Fluid Transport Mechanisms**	Nathan Brimall, NASA-Ames
EM Passive Imaging as a Hazards Assessment Methodology	Dante Fratta – University of Wisconsin-Madison	**Education and Outreach**	Subsurface Imaging and Sensing Team
3-D passive electromagnetics for structural imaging, anisotropy, and methodological studies	Paul Bedrosian, US Geological Survey, Denver	**Understanding the complexity of the crustal Earth system**	Christian Klose, Columbia University

Also, imaging support to many other ISEs

Subsurface Imaging and Sensing

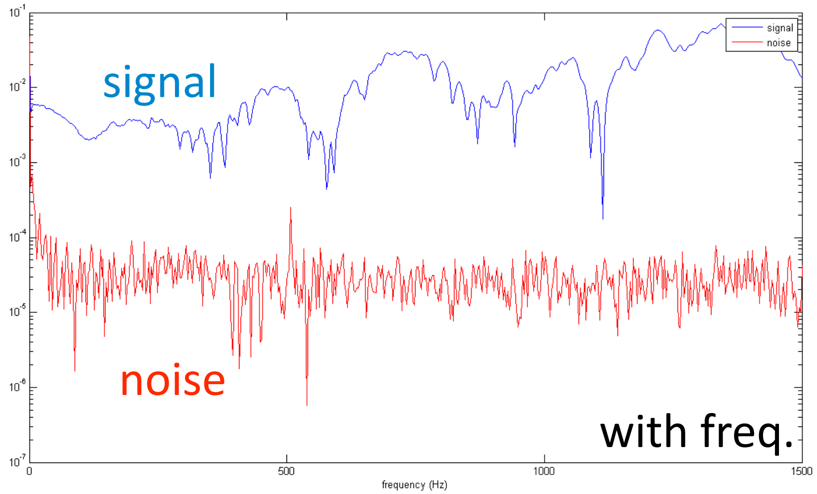
Passive Seismic Stations – Currently Running

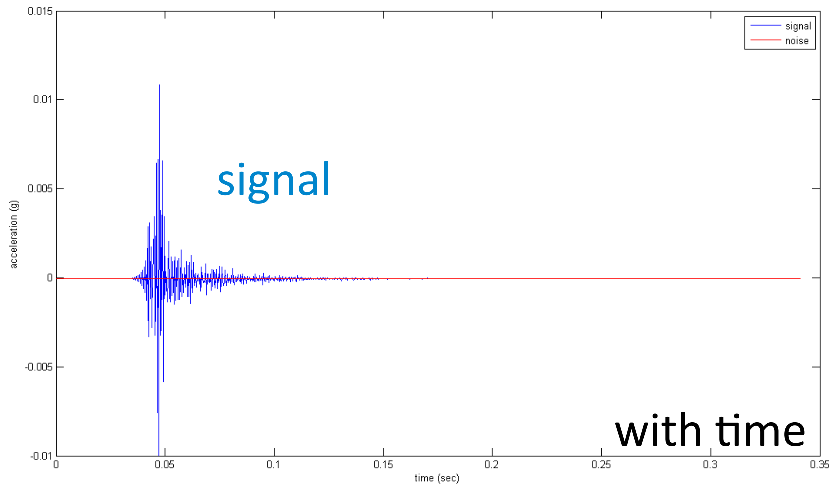
Observatory station #1

- ✓ Slurry Pumphouse control shack
- ✓ Sonde sanded in at 500', 6" hole
- ✓ Water level at 200'

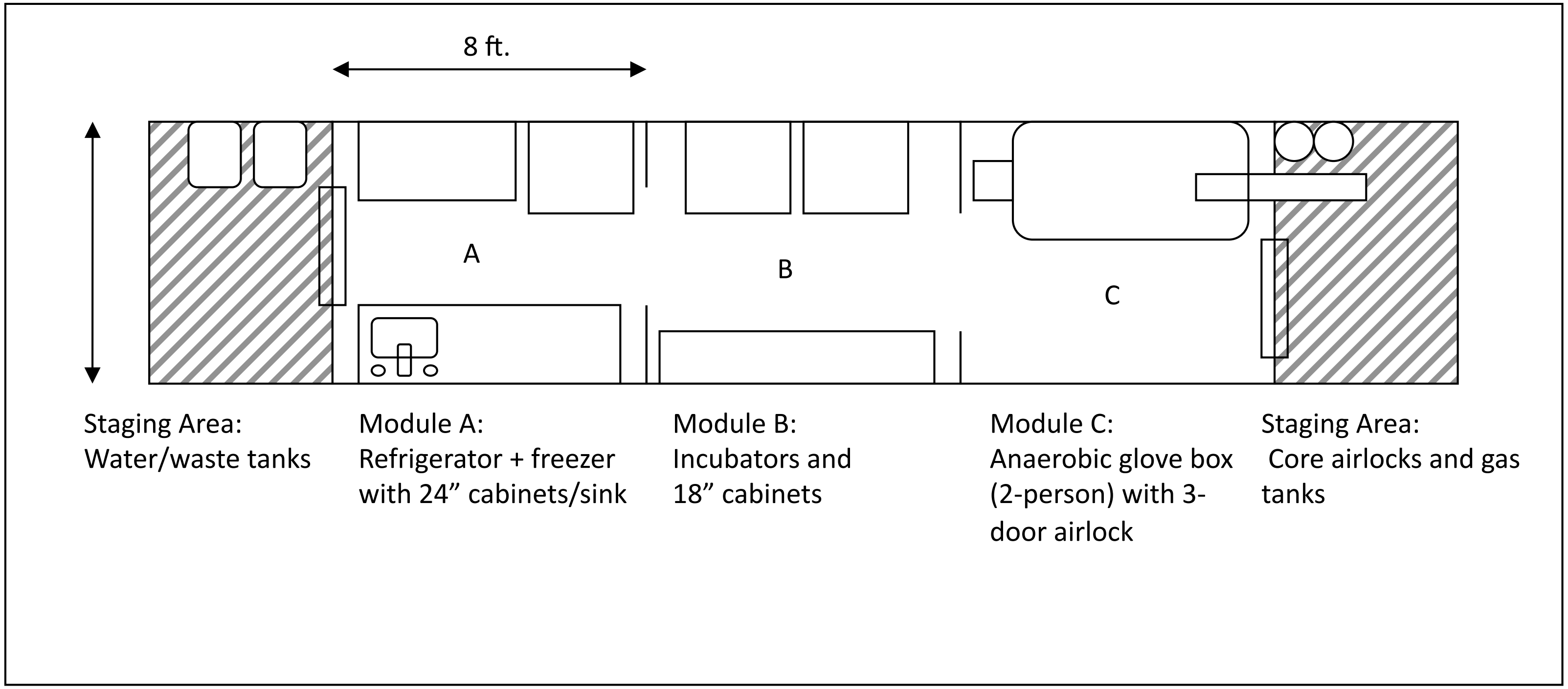
Observatory station #2

- ✓ 2000 m from hoistway
- ✓ Sonde grouted in at 45', 6" hole
- ✓ Dry



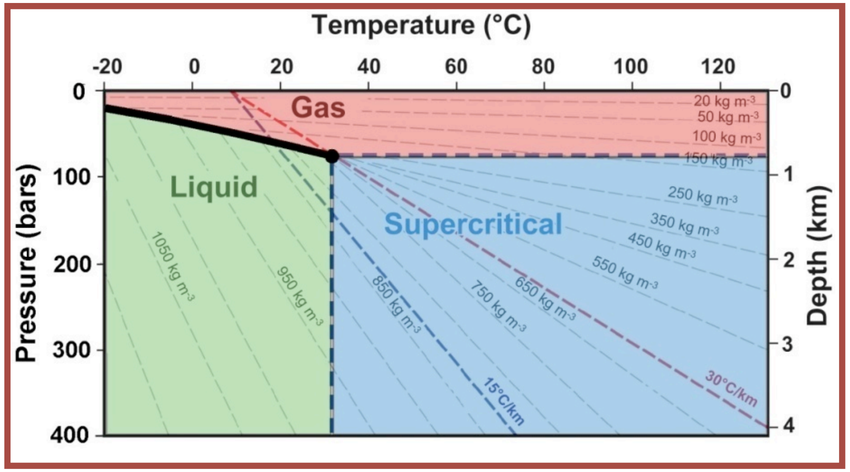


Mobile Underground Laboratory for Experimentation

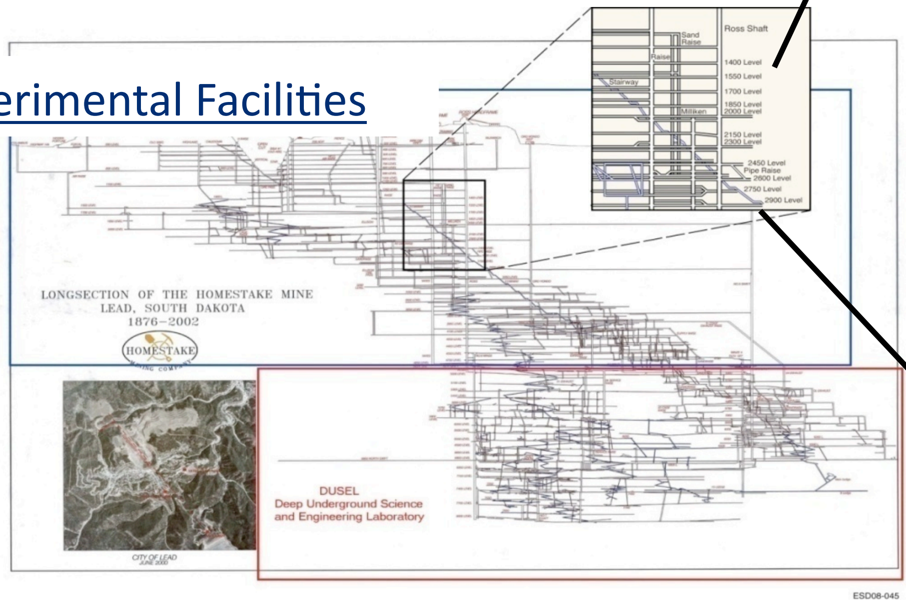


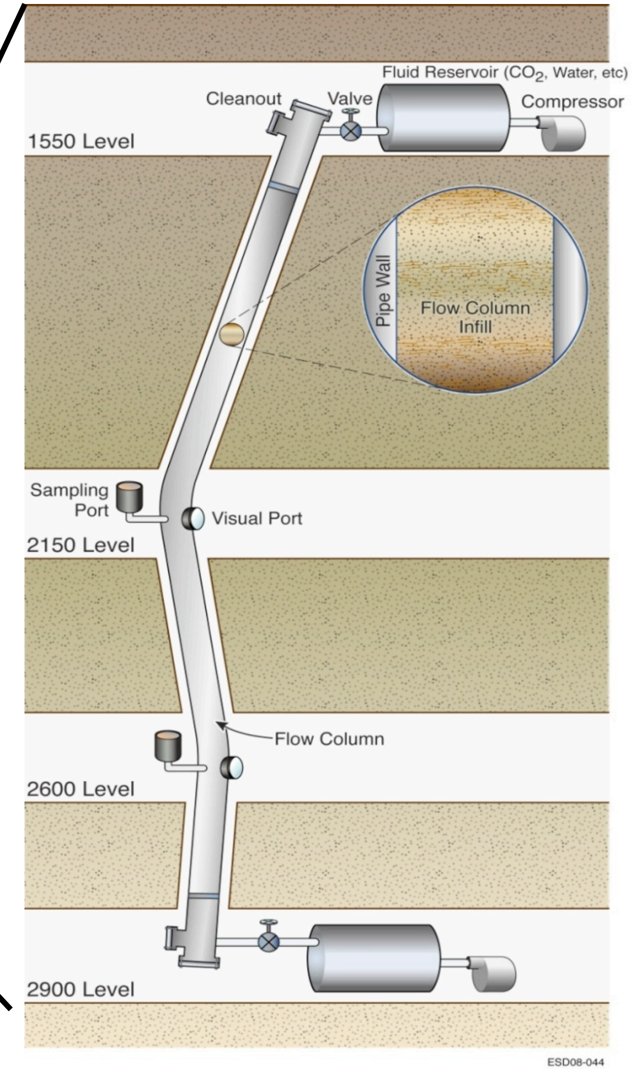
- Modular and portable for transport through small mine passages.
- Provides clean, controlled environment.
- Flexible in footprint and in equipment content.
- Meets safety requirements.

CO_2 Sequestration Experiment



Experimental Facilities





Coupled Thermal-Hydrological-Mechanical-Chemical-Biological Processes Experimental Facility

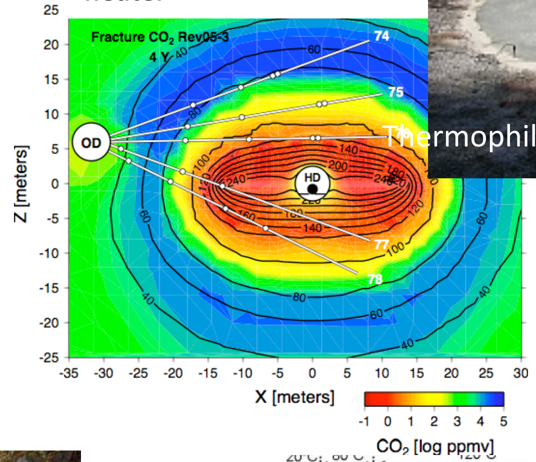
Key Scientific Question:
How do mechanical and transport properties evolve and influence fluid chemistry and microbial populations?

Intellectual Merit:
Advance understanding of fault zones, geothermal reservoirs, magmatic-hydrothermal systems, ore mineralization, radioactive waste, other.

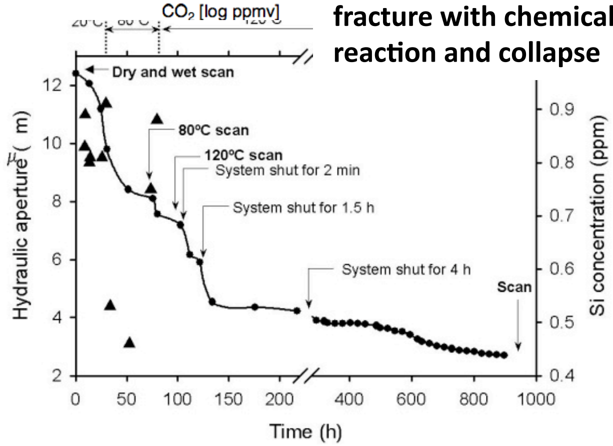
Process interactions and feedbacks are scale-dependent, complex and often enigmatic - requiring large-scale well-controlled *in-situ* experiments to understand response.


Thermophile-bearing hot spring

Modeled concentration of chemical species around heater




High-grade gold vein



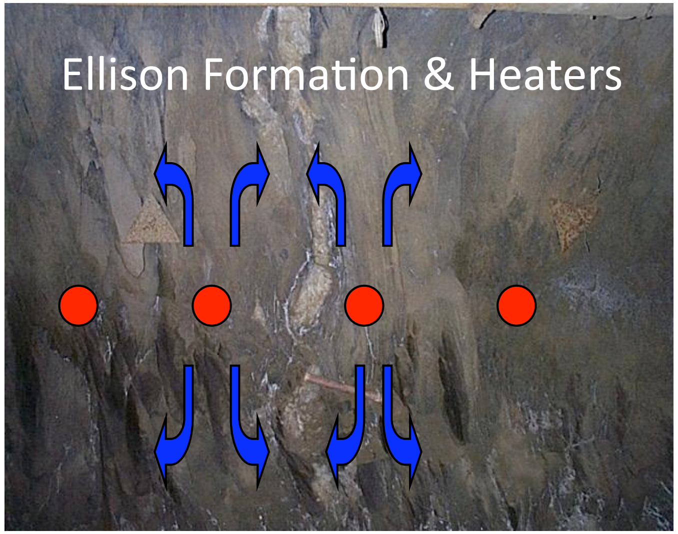
Permeability-drop in fracture with chemical reaction and collapse

Coupled THMCB Processes Experimental Facility

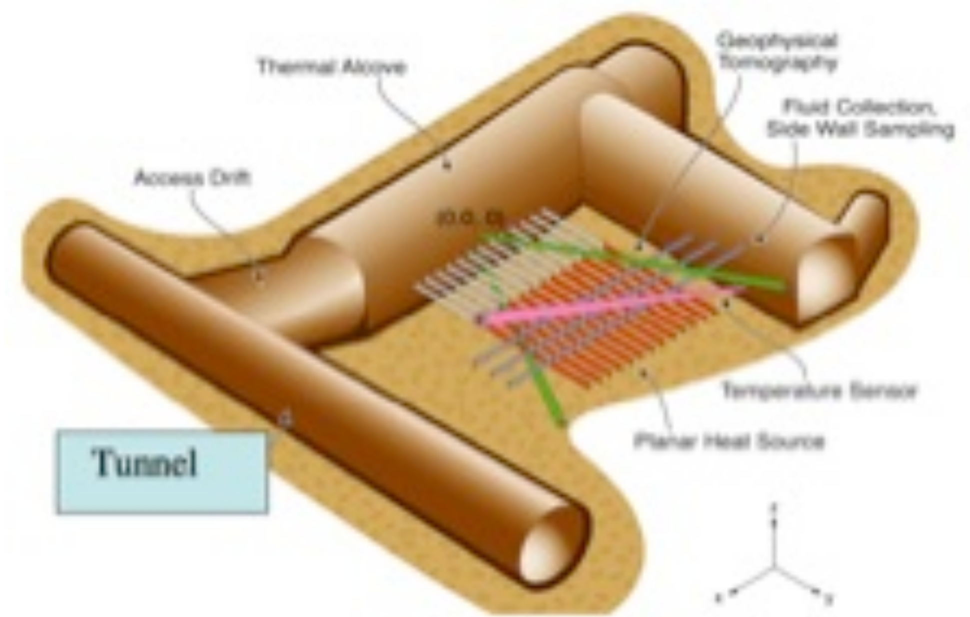
Experimental Approach

a.) characterize site, b.) install infrastructure c.) heat d.) monitor e.) core samples d.) excavate (*mine back*) and describe.

- **Hydrothermal Convection**
- **Biological Gradient Test**
- **Effective Reaction Rates**



Experimental Layout



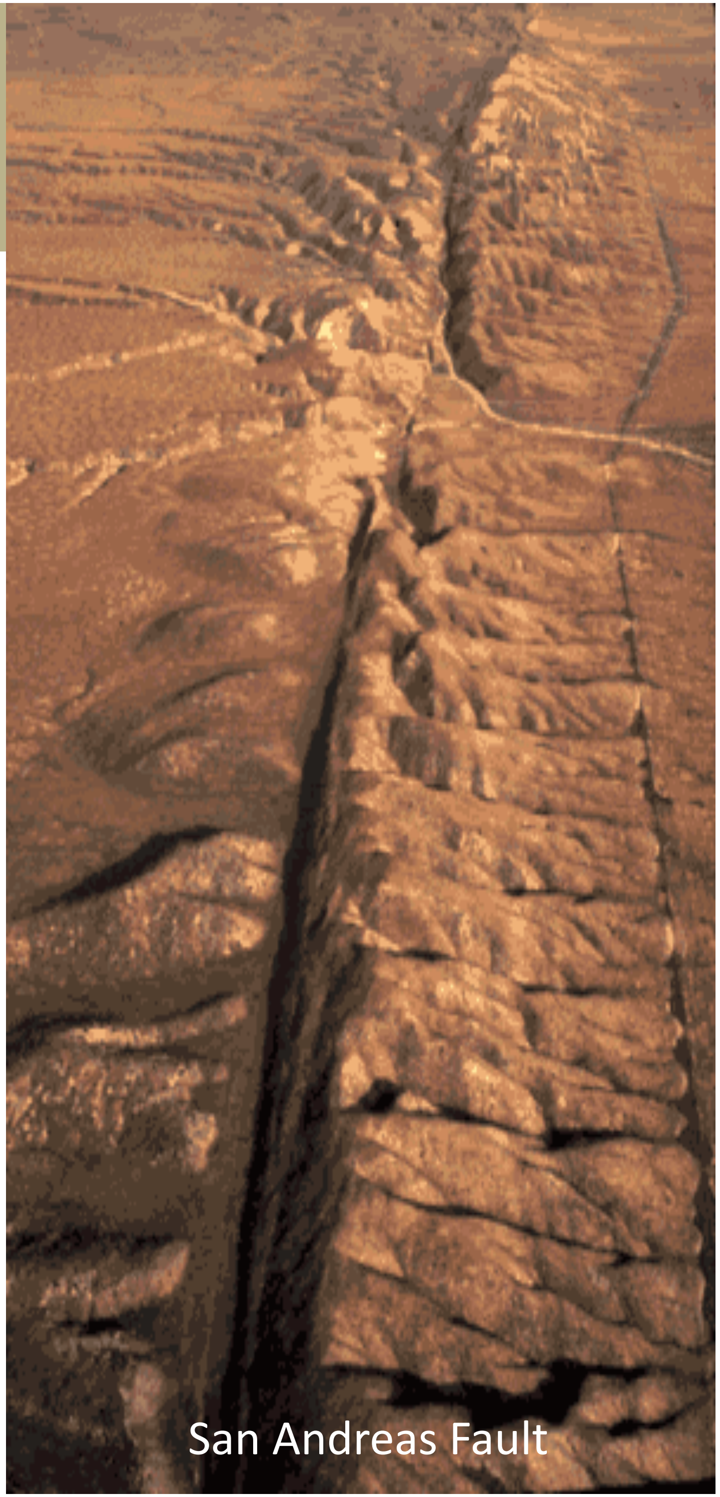
THMCB S4 Tasks

- Select candidate rock mass and tunnel complexes based on geological, mineralogical, hydrological and fracture data
- Preliminary design, refined through the following steps of characterization and pre-test modeling:
  - Laboratory experiments
  - Modeling
  - Evaluation of new technologies
- Development of **WBS**
- Working group meetings to refine design and costs

Faulting Processes Experiment

Hypothesis: Faulting processes change with scale, so small laboratory experiments are incomplete representations of real faults. Larger experiments are needed to advance understanding of faulting.

Faulting Processes
Propagation in intact rock
Gouge development
Friction laws
Fault reactivation
Corresponding seismic response
Fluid effects
Microbial interactions
Sealing and healing
many others….

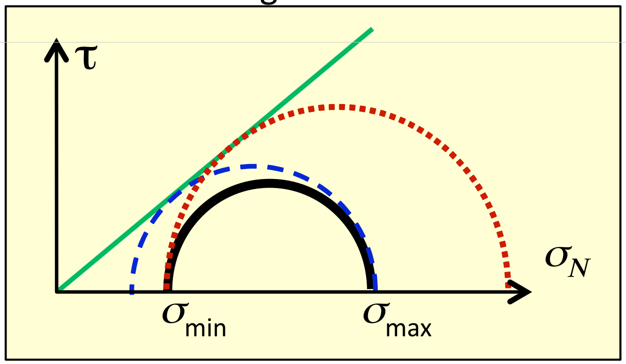


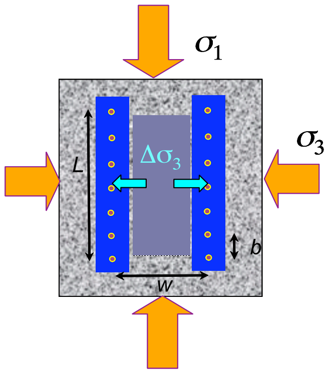
San Andreas Fault

Faulting Processes Experiment

Approach

- Faulting by either increasing or decreasing stress



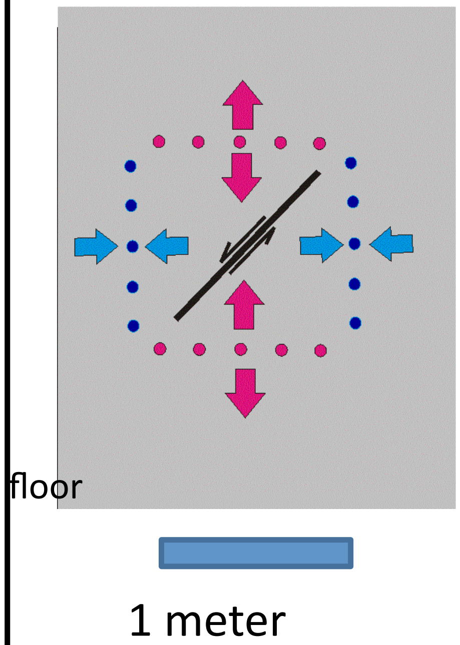


Cooling two rows of boreholes to change stress→ cause faulting

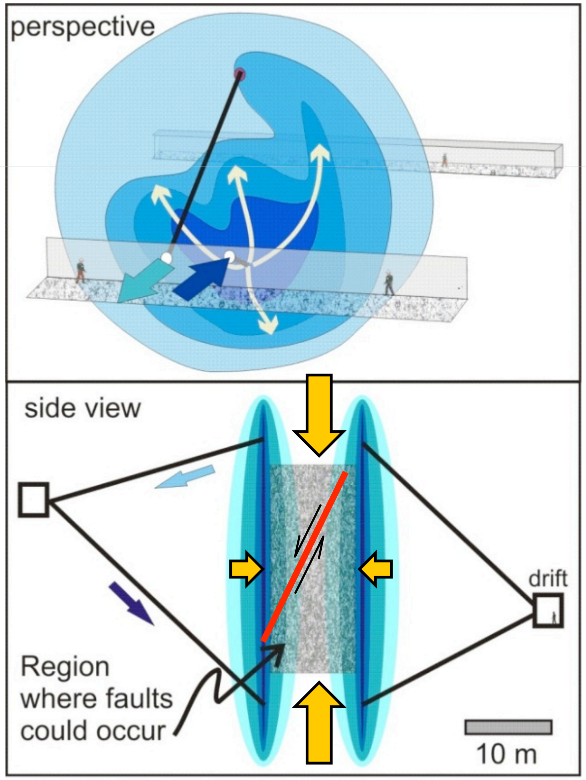
Facilities

Thermal panels to manipulate stresses

300L Facility



Deep Facility



Cavity Facility

as above, but located in area to be excavated→ *Mine back*

Cavern Design for the DUSEL

Bobet and others

Objective:

Extend observational method by conducting rock mechanics research prior to and in early phase of the development of DUSEL Homestake to assist in design, construction and operation of the underground development (with special emphasis on large cavern).

Approach

Ten subprojects on

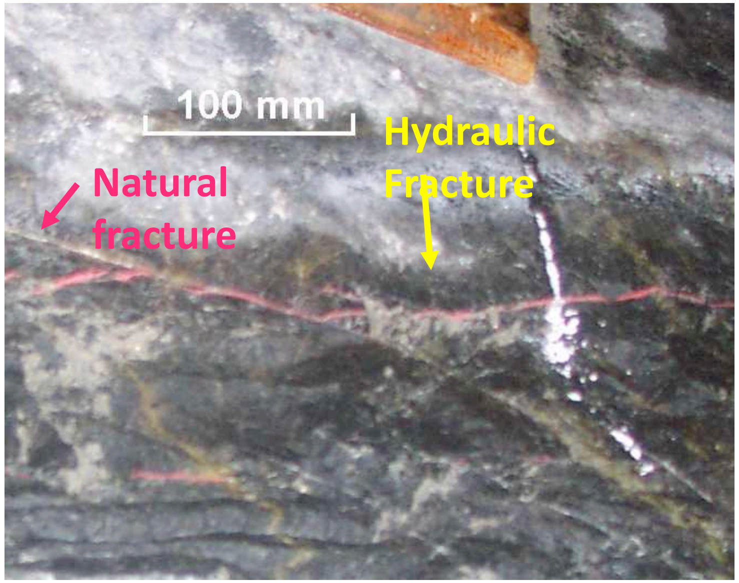
- Rock mass and fracture characterization (6 subprojects)
  - 3-D mapping, Lidar, New theoretical models, Geophysics
- Special aspects of analysis and design (2 subprojects)
  - Cavern design, novel cutting techniques
- *Mine back* experiment for upscaling (1 subproject)
- Risk analysis (1 subproject)

will be developed in detail in 2 workshops and individual activities of the involved researchers. The proposals for these subprojects will then be submitted for S-5.

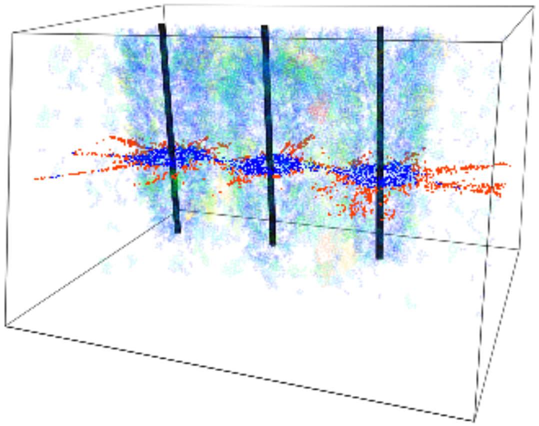
Mechanics of Engineered Fractures in Discontinuous Rock

E. Detournay, PI; J. Labuz, co-PI; w/ 7 other investigators

Objective: Advance understanding of fractures created for engineering applications (e.g. hydraulic fracturing or blasting for preconditioning rock masses).



Interactions between hydraulic and natural fractures



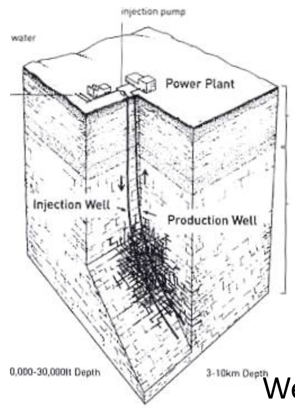
Simulating blast-induced fracturing

<u>Research issues</u>

- Crack initiation
- Energy scaling
- Crack interactions
- Interface fracture
- Shear opening mechanisms
- Coupled processes
- Microseismics & imaging

Approach

1. Characterize site
2. Field test, hydraulic fracture
3. *Mine back*, describe
4. Simulations
5. Instrument blasting for large cavity. Simulate

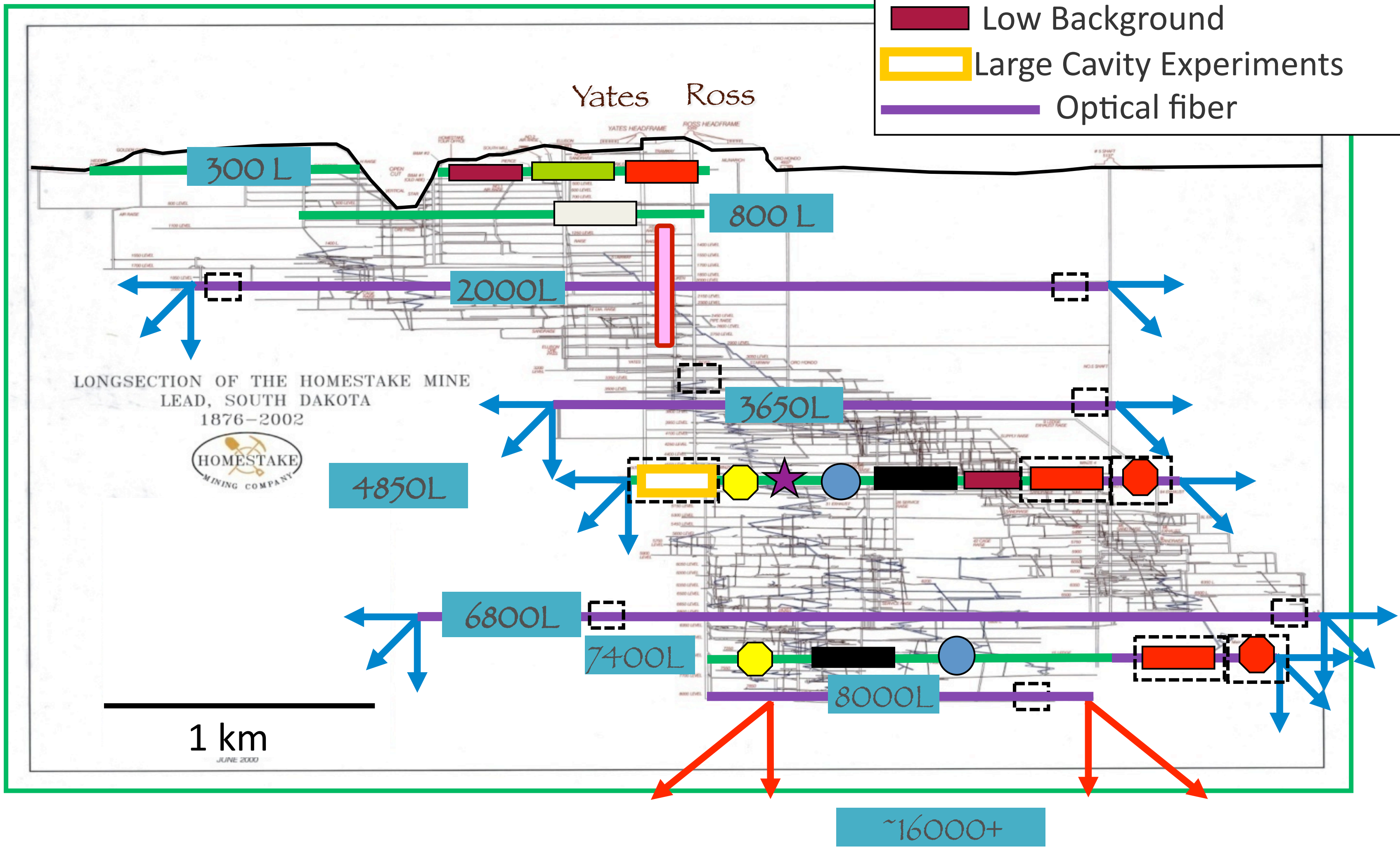


Well stimulation

BGE Facilities

BioGeoEng (+Phys)

- Deep Ecohydrology
- Subsurface Imaging and Sensing
- CO_2 Sequestration
- Coupled THMCB Processes
- Faulting Processes
- Low Background
- Large Cavity Experiments
- Optical fiber



BGE-Physics Interactions

- Large Cavity Design and Construction – Einstein – Friday 3:45
- Mobile Underground Laboratories – Pfiffner Fri. 4:30
- Low Background Counting Facility– Bout – Thurs. 4:30
- Cherenkov Water Purification Facility – Bout – Thurs. 4:30
- Fluorescent Tracer Detection – Glaser – Fri. 3:00